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(54) **CERAMIC COMPOSITE VANE WITH METALLIC SUBSTRUCTURE**

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(52) **U.S. Cl.** .... **416/229 A**; 416/241 B

(58) **Field of Search** .... 416/97 R, 96 A, 416/229 A, 241 B; 415/209, 210, 191, 115, 200

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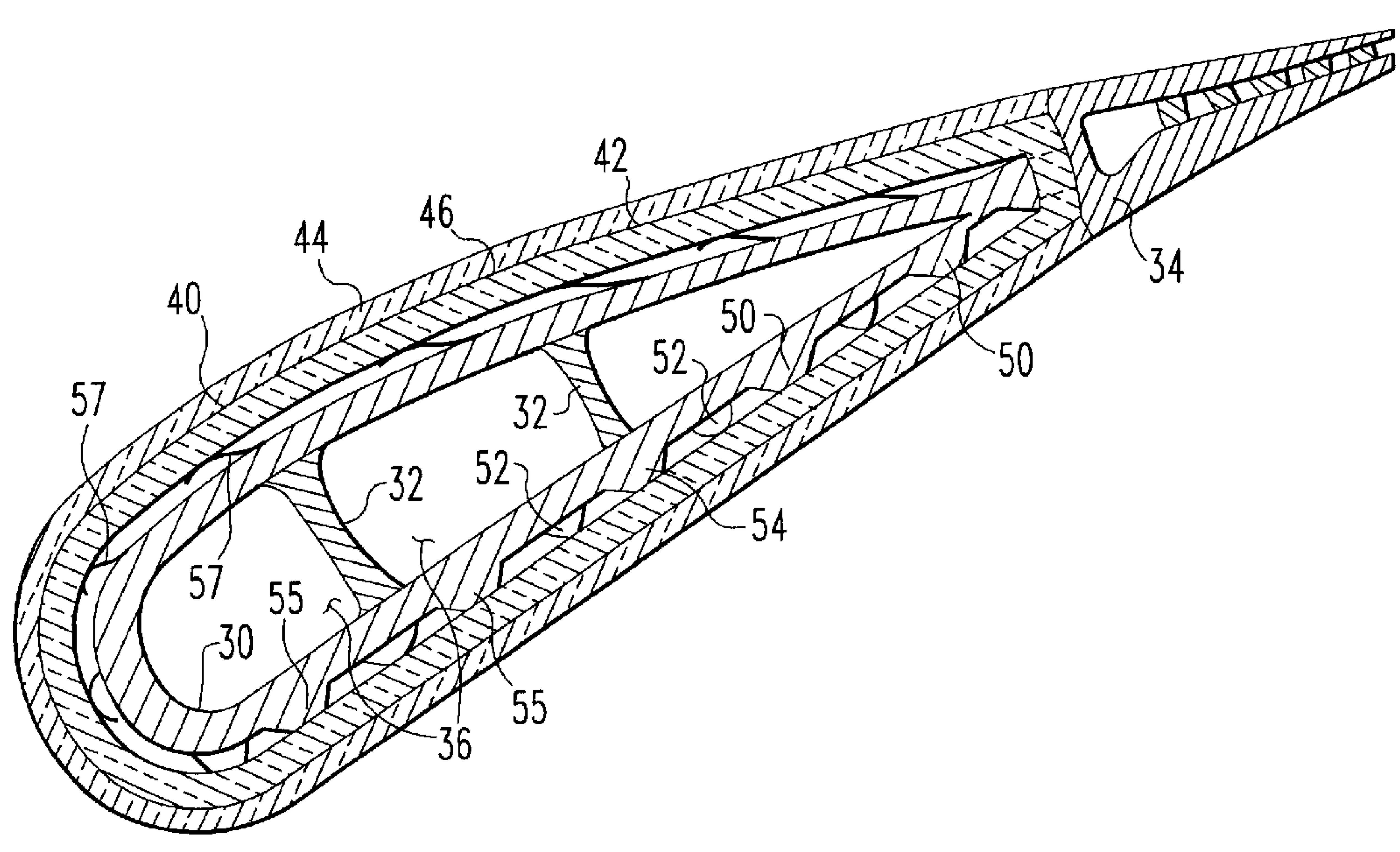
(57) **ABSTRACT**

A vane assembly for a turbine assembly includes an inner endcap, an outer endcap, and a body. The body includes a metallic core assembly, a ceramic shell assembly and a support assembly. The metallic core assembly is coupled to the inner and outer endcaps and bears most of the mechanical loads, including aerodynamic loads. The ceramic shell bears substantially all of the thermal stress placed on the vane assembly. The support assembly is disposed between the metallic core assembly and said ceramic shell assembly and is coupled to the metallic core assembly.

54 Claims, 6 Drawing Sheets



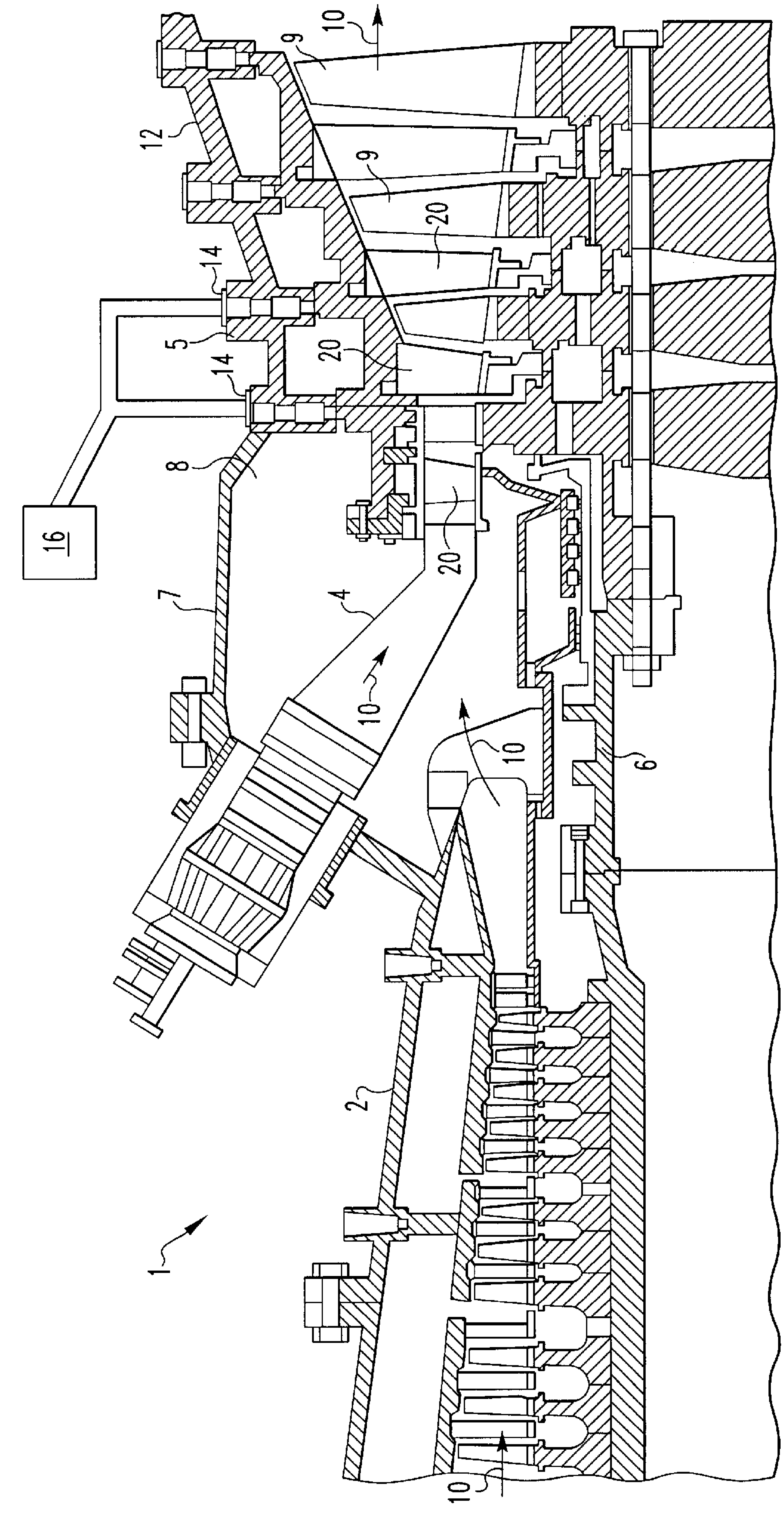


FIG.1

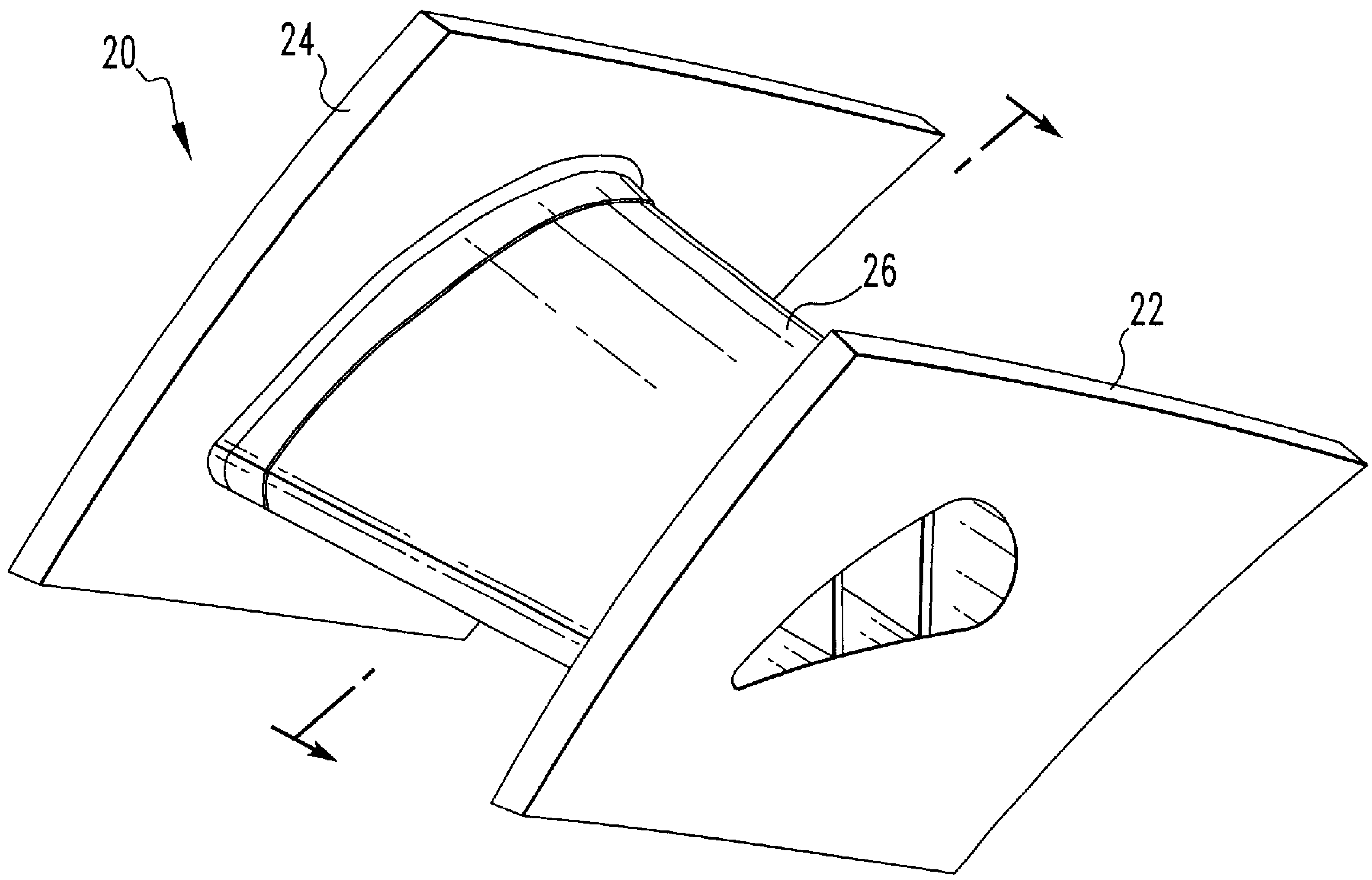


FIG.2

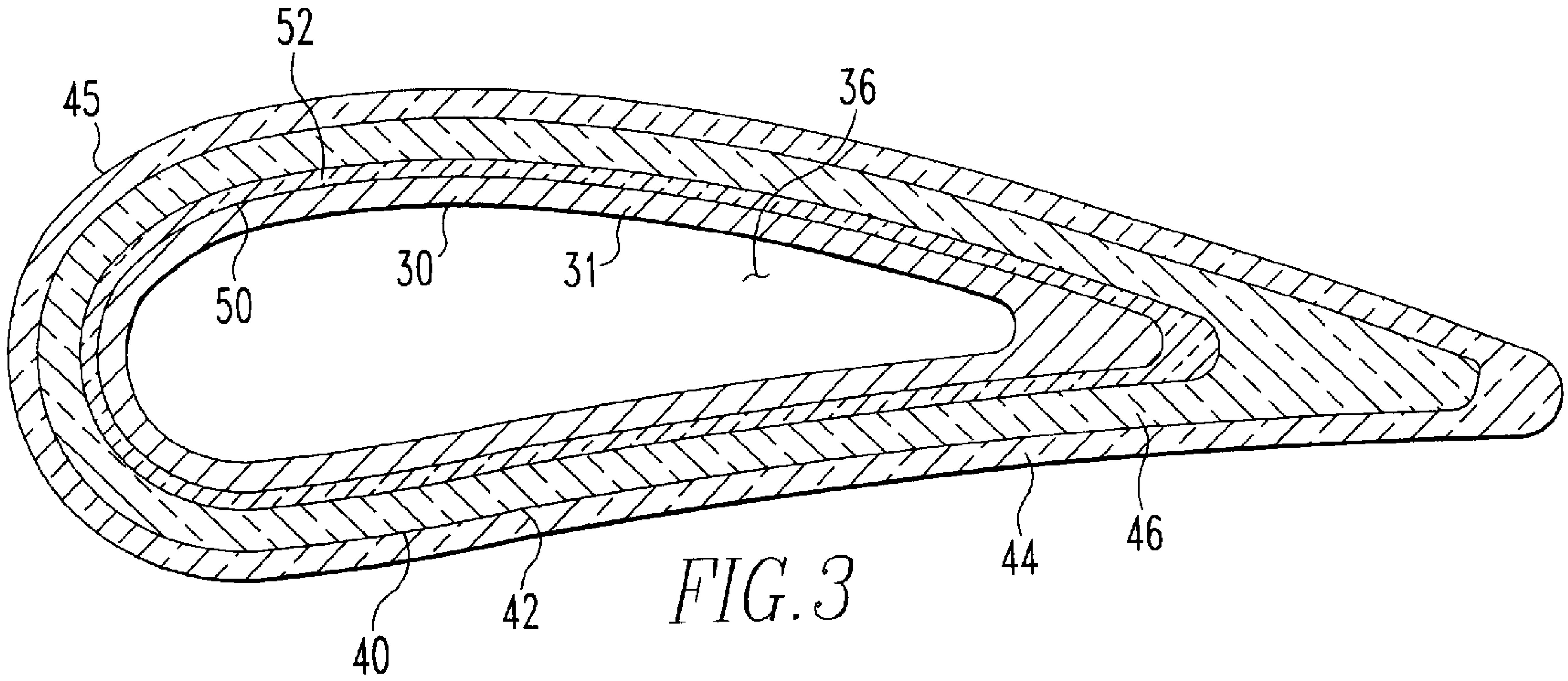


FIG. 3

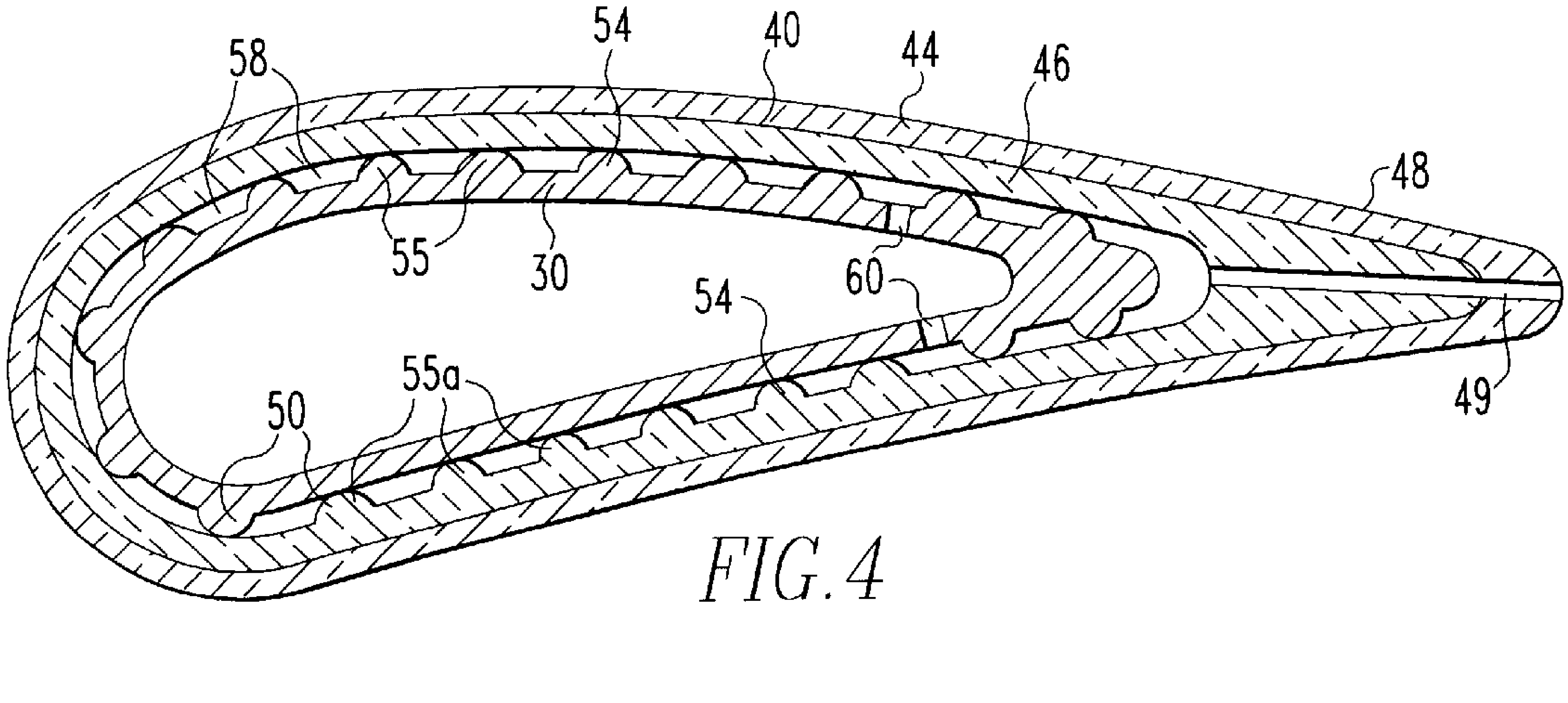


FIG. 4

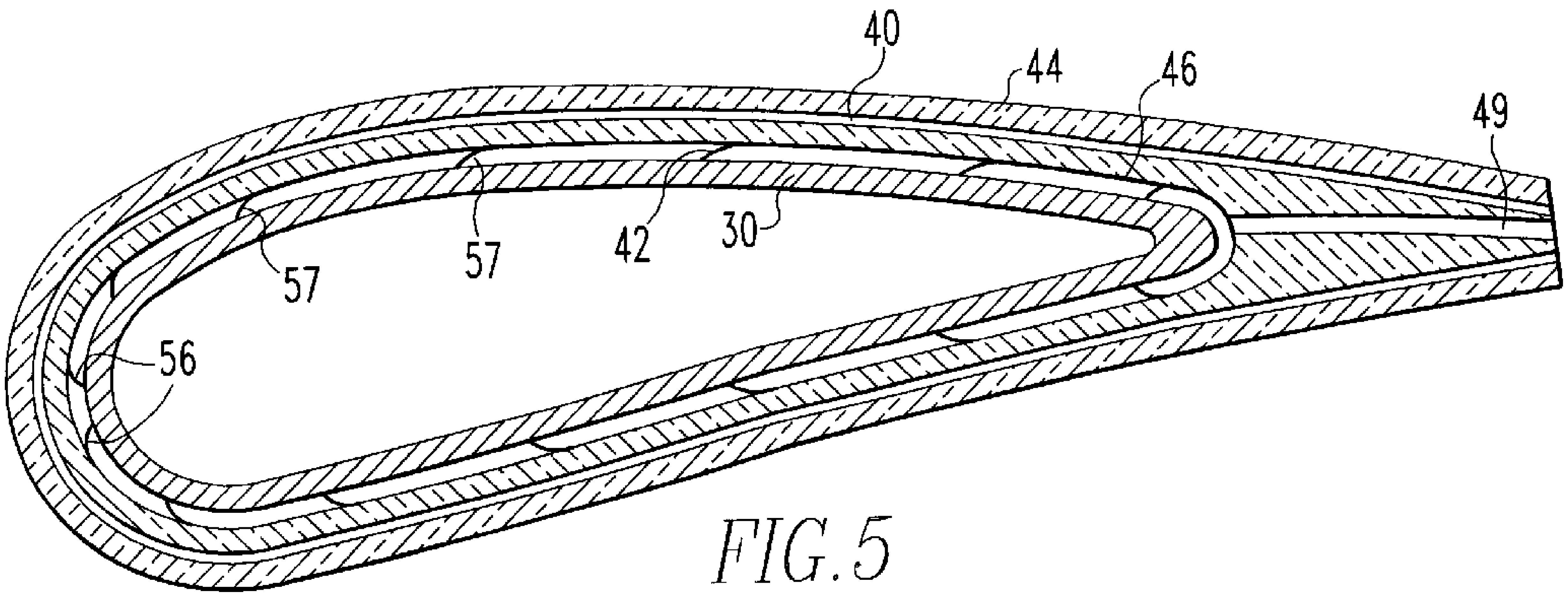
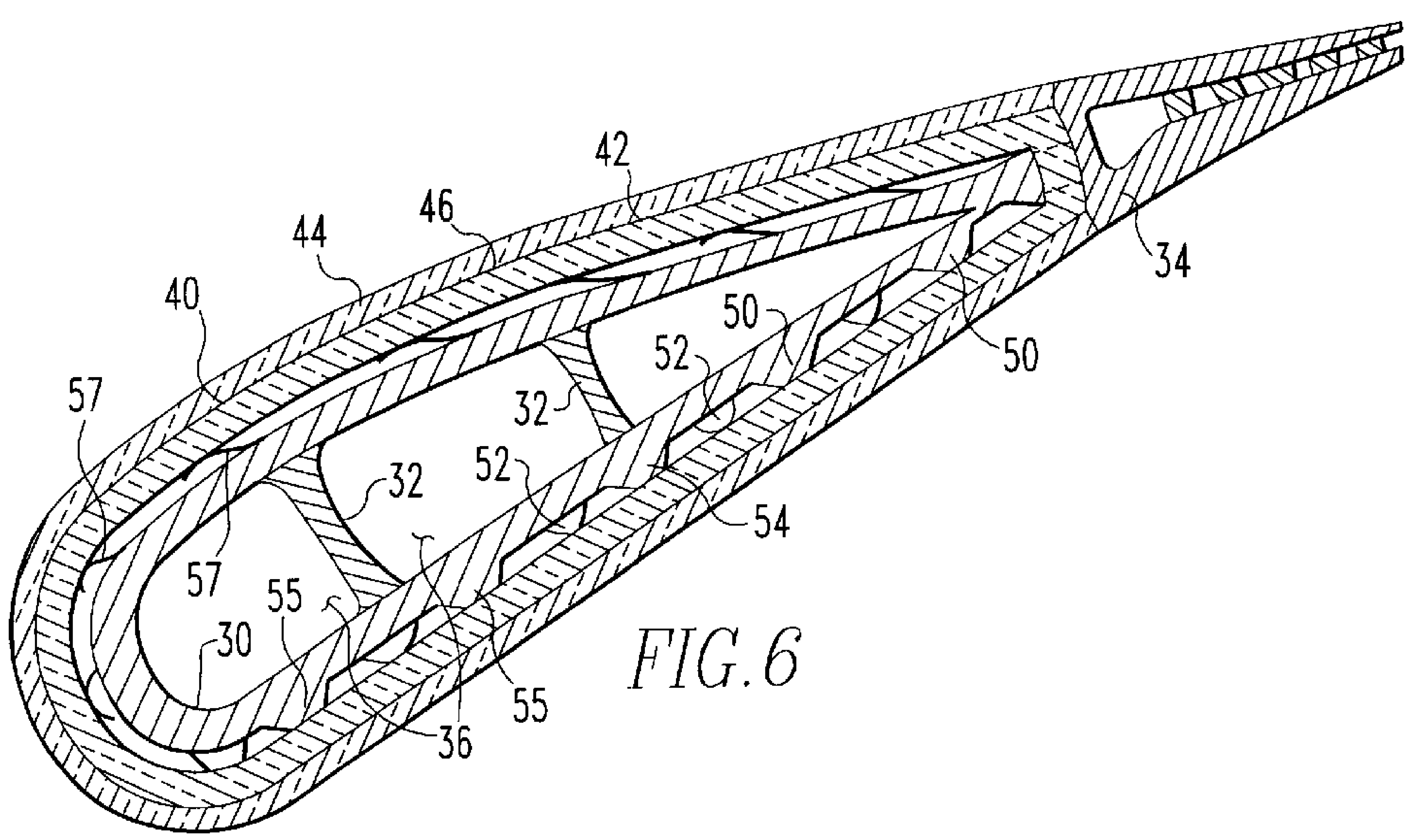

40
44
46
49
57
57
42
30
56

FIG.5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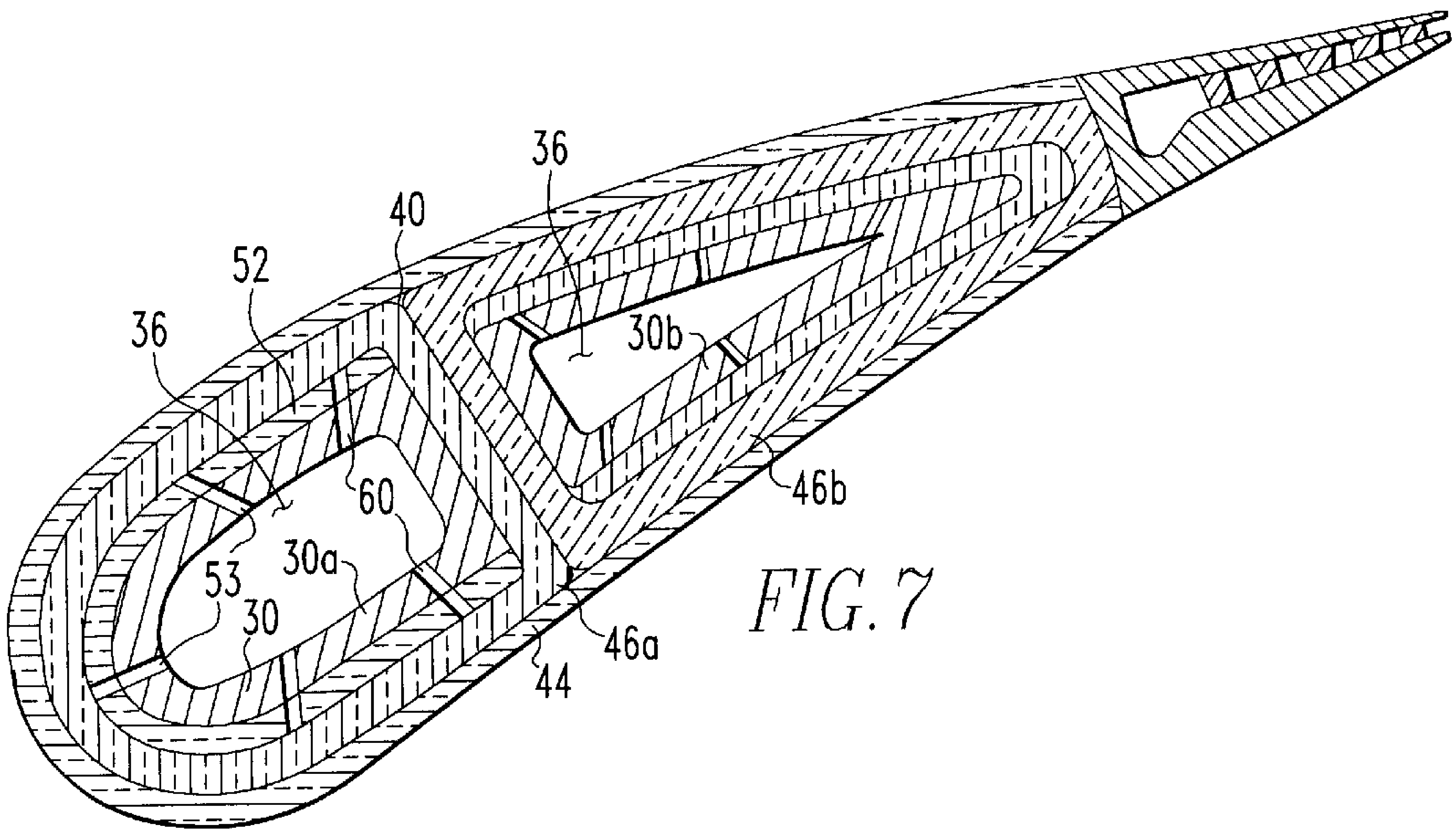
30
55
36

FIG.6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40
52
36
30b
60
46b
53
30a
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46a
44

FIG. 7

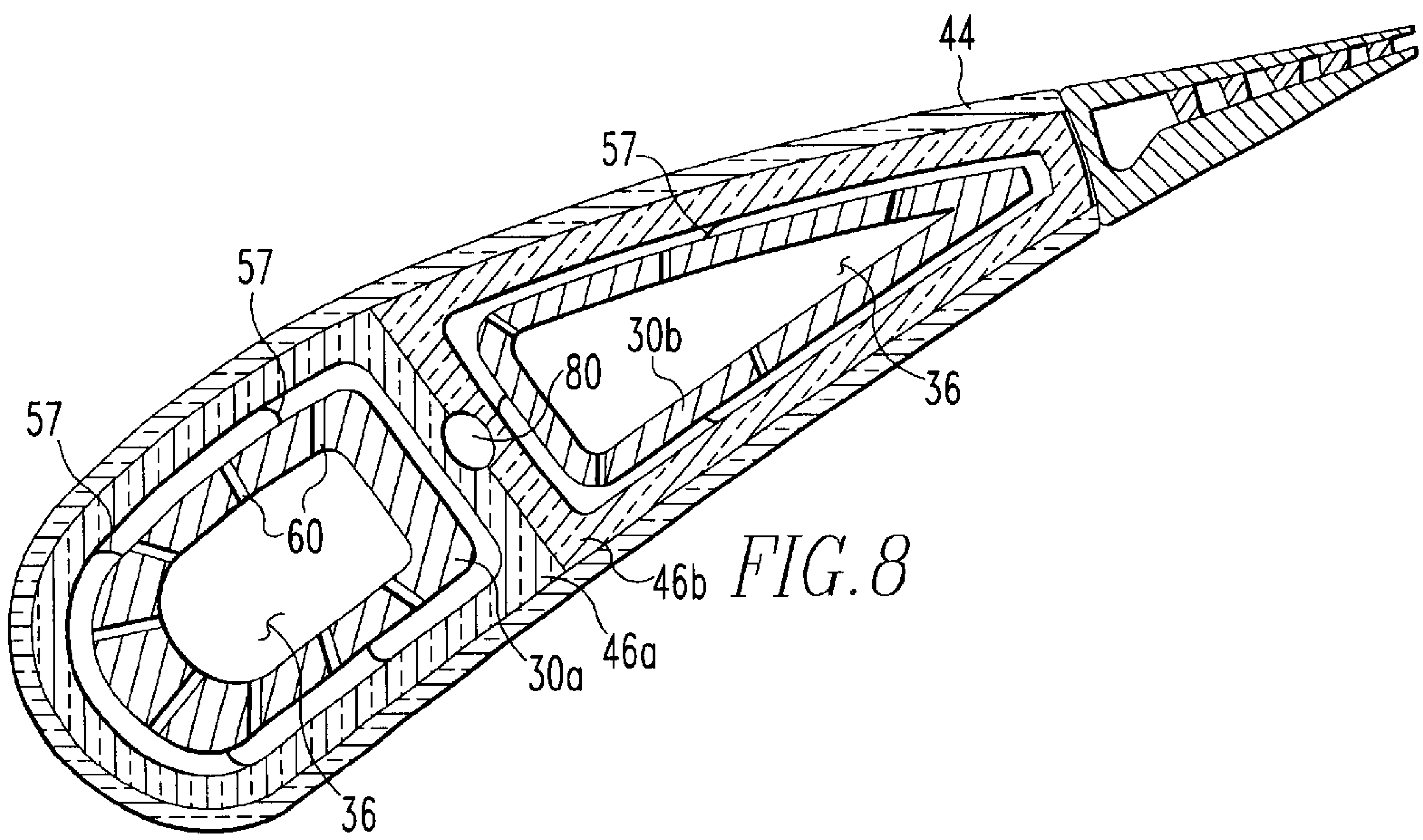
44
57
57
30b
80
57
36
60
46b
30a
46a
36

FIG. 8

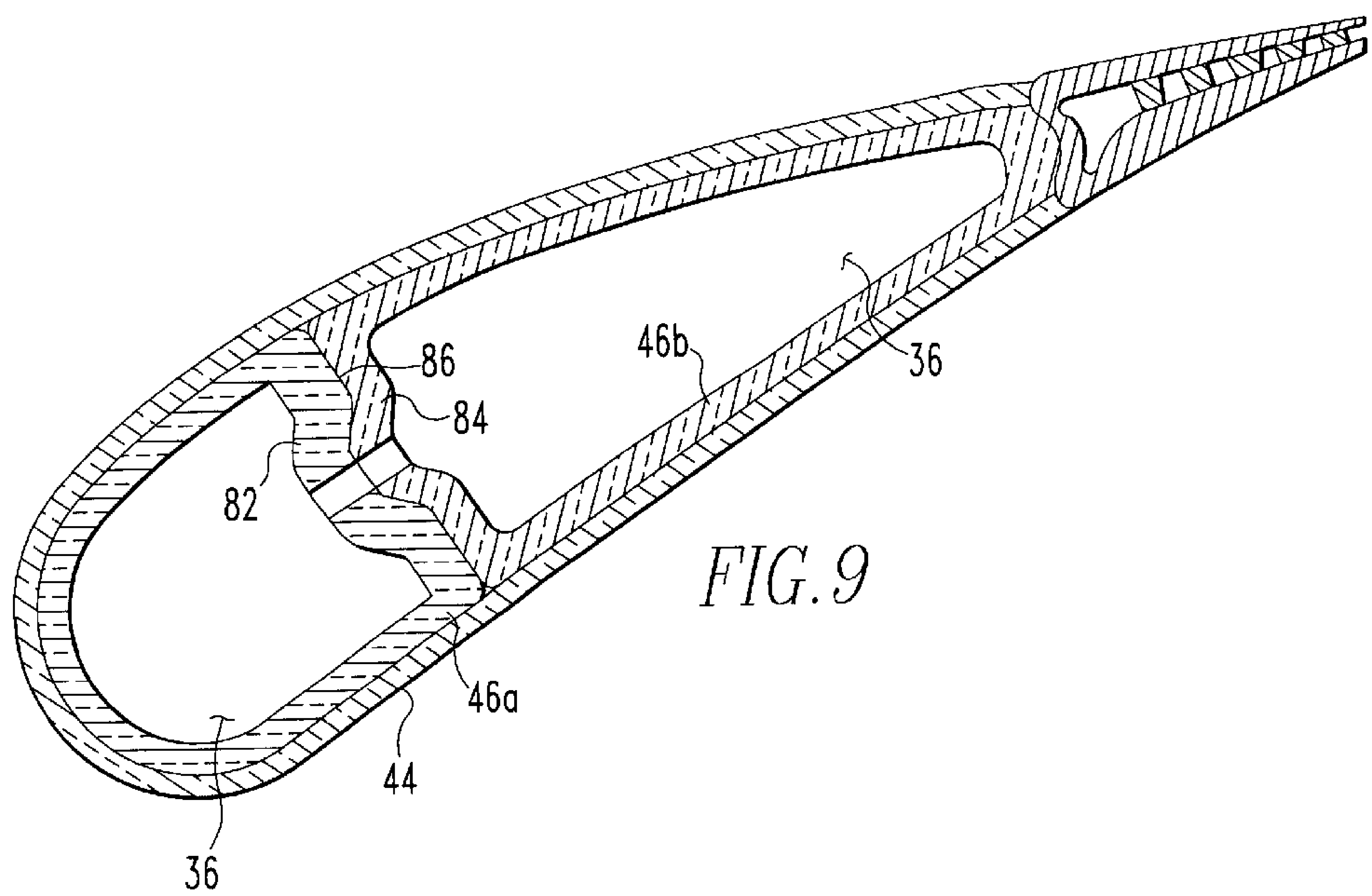
86
84
82
46b
36
46a
44
36

FIG.9

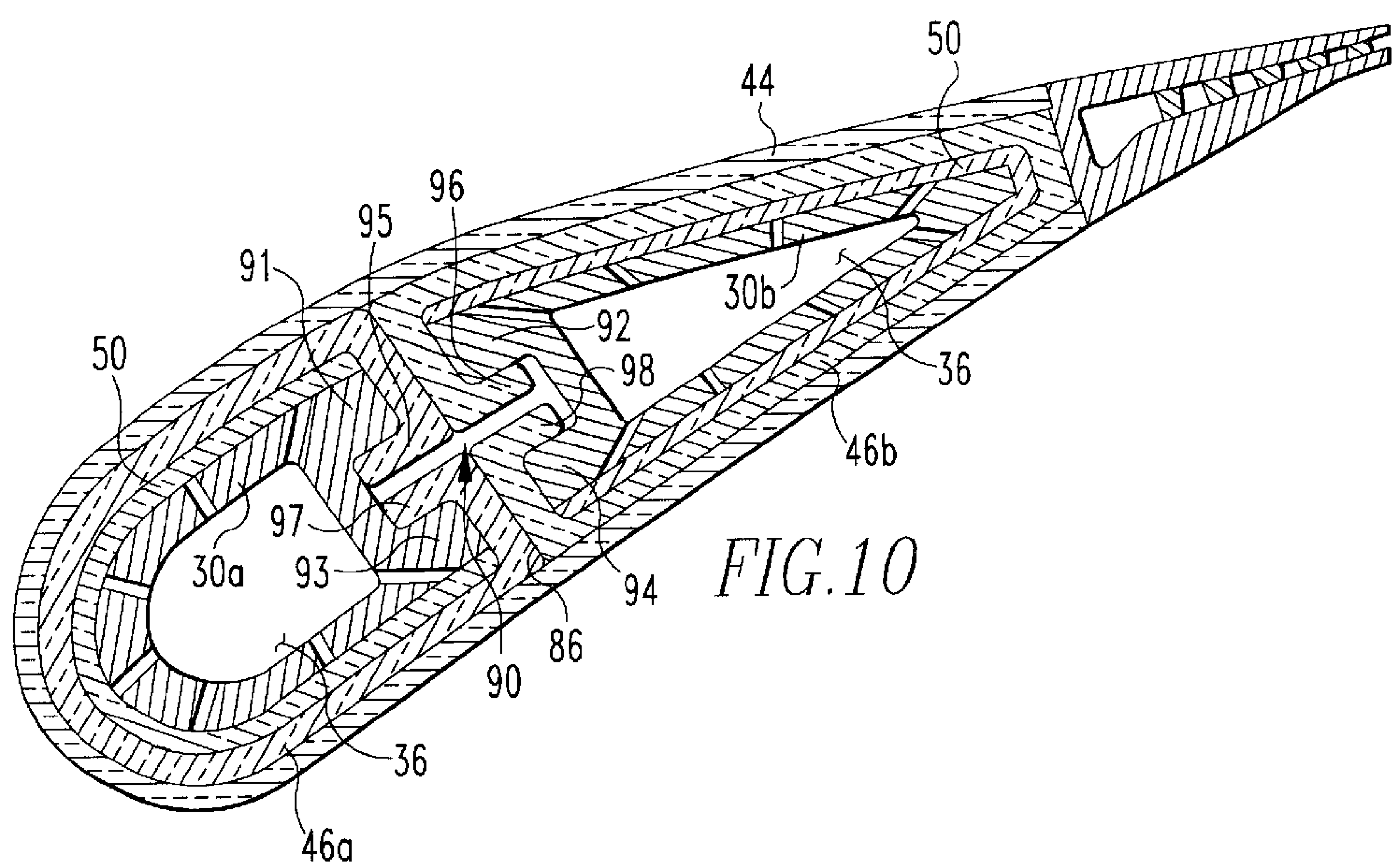
50
44
96
95
91
50
92
30b
98
36
46b
97
30a
93
94
86
90
36
46a

FIG.10

CERAMIC COMPOSITE VANE WITH METALLIC SUBSTRUCTURE

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to the vanes of a turbine assembly and, more specifically, to a ceramic composite vane having a metallic substructure.

2. Background Information

Combustion turbine power plants, generally, have three main assemblies: a compressor assembly, a combustor assembly, and a turbine assembly. In operation, the compressor assembly compresses ambient air. The compressed air is channeled into the combustor assembly where it is mixed with a fuel. The fuel and compressed air mixture is ignited creating a heated working gas. The heated working gas is typically at a temperature of between 2500 to 2900° F. (1371 to 1593° C.). The working gas is expanded through the turbine assembly. The turbine assembly includes a plurality of stationary vane assemblies and rotating blades. The rotating blades are coupled to a central shaft. The expansion of the working gas through the turbine assembly forces the blades to rotate creating a rotation in the shaft.

Typically, the turbine assembly provides a means of cooling the vane assemblies. The first row of vane assemblies, which typically precedes the first row of blades in the turbine assembly, is subject to the highest temperature of working gas. To cool the first row of vane assemblies, a coolant, such as steam or compressed air, is passed through passageways formed within the vane structure. These passageways often include an opening along the trailing edge of the vane to allow the coolant to join the working gas.

The cooling requirements for a vane assembly can be substantially reduced by providing the vane assembly with a ceramic shell as its outermost surface. Ceramic materials, as compared to metallic materials, are less subject to degrading when exposed to high temperatures. Ceramic structures having an extended length, such as vanes associated with large, land based turbines, are less able to sustain the high mechanical loads or deformations incurred during the normal operation of a turbine vane. As such, it is desirable to have a turbine vane that incorporates a metallic substructure, which is able to resist the mechanical loads on the vane, and a ceramic shell, which is able to resist high thermal conditions.

Prior art ceramic vane structures included vanes constructed entirely of ceramic materials. These vanes were, however, less capable of handling the mechanical loads typically placed on turbine vanes and had a reduced length. Other ceramic vanes included a ceramic coating which was bonded to a thermal insulation disposed around a metallic substructure. Such a ceramic coating does not provide any significant structural support. Additionally, the bonding of the ceramic coating to the thermal insulation precludes the use of a composite ceramic. Additionally, because the ceramic was bonded to the insulating material, the ceramic could not be cooled in the conventional manner, i.e., passing a fluid through the vane assembly. The feltmetal typically has a lower tolerance to high temperature than the metallic substructure, thus additional cooling was required.

Alternative ceramic shell/metallic substructure vanes include vanes having a ceramic leading edge and a metallic vane body, and a rotating blade having a metallic substructure and a ceramic shell having a corrugated metal partition

therebetween. These structures require additional assembly steps during the final assembly of the vane or blade which are time-consuming and require a rotational force to activate certain internal seals.

There is, therefore, a need for a composite ceramic vane assembly for a turbine assembly having a metallic core assembly with attached support structures and a ceramic shell assembly.

There is a further need for a composite ceramic vane assembly having a ceramic shell assembly which is structured to be cooled by the cooling system for the vane assembly.

There is a further need for a composite ceramic vane assembly which transmits the aerodynamic forces of the ceramic shell assembly to the metallic core assembly without imparting undue stress to the ceramic shell assembly.

There is a further need for a composite ceramic vane assembly which accommodates differential thermal expansion rates between the ceramic shell assembly and the metallic core assembly while maintaining a positive pre-load on the ceramic shell assembly.

SUMMARY OF THE INVENTION

These needs, and others, are satisfied by the invention which provides a turbine vane assembly having a ceramic shell assembly and a metallic core assembly. The metallic core assembly includes an attached support assembly. The metallic core assembly includes passages for a cooling fluid to pass therethrough. The support assembly is structured to transmit the aerodynamic forces of the ceramic shell assembly to the metallic core assembly without imparting undue stress to the ceramic shell assembly. The support assembly can be any one of, or a combination of, a compliant layer, such as a feltmetal, contact points, such as a raised ribs or dimples on the metallic core assembly, or a biasing means, such as a leaf spring.

The metallic core assembly includes at least one cooling passage therethrough. The ceramic shell assembly has an exterior surface, which is exposed to the working gas, and an interior surface. The ceramic shell assembly interior surface is in fluid communication with the metallic core assembly cooling passage. For example, if the ceramic shell assembly is supported by ribs on the metallic core assembly, a cooling fluid may pass between adjacent ribs. If the ceramic shell assembly is supported by a biasing means, the cooling fluid may be passed over the biasing means. If the ceramic shell assembly is supported by a compliant layer, the compliant layer may have cooling passages formed therein.

BRIEF DESCRIPTION OF THE DRAWINGS

A full understanding of the invention can be gained from the following description of the preferred embodiments when read in conjunction with the accompanying drawings in which:

FIG. **1** is a cross sectional view of a compressor turbine power plant.

FIG. **2** is an isometric view of a vane assembly.

FIG. **3** is a cross-sectional view of a metallic core assembly, ceramic shell assembly, and support assembly comprising a layer of feltmetal.

FIG. **4** is a cross-sectional view of a metallic core assembly, ceramic shell assembly, and a support assembly comprising a plurality of contact points.

FIG. **5** is a cross-sectional view of a metallic core assembly, ceramic shell assembly, and a support assembly comprising a biasing means such as leaf springs.

FIG. 6 is a cross-sectional view of a metallic core assembly, ceramic shell assembly, and a support assembly comprising a layer of feltmetal, a plurality of contact points, and a biasing means.

FIG. 7 is a view of an alternate embodiment.

FIG. 8 is a view of an alternate embodiment.

FIG. 9 is a view of an alternate embodiment.

FIG. 10 is a view of an alternate embodiment.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

As is well known in the art and shown in FIG. **1**, a combustion turbine **1** includes a compressor assembly **2**, at least one combustor assembly **3**, a transition section **4**, and a turbine assembly **5**. A flow path **10** exists through the compressor assembly **2**, combustor assembly **3**, transition section **4**, and turbine assembly **5**. The turbine assembly **5** is mechanically coupled to the compressor assembly **2** by a central shaft **6**. Typically, an outer casing **7** encloses a plurality of combustor assemblies **3** and transition sections **4**. The outer casing **7** creates a compressed air plenum **8**. The combustor assemblies **3** and transition sections **4** are disposed within the compressed air plenum **8**. The combustor assemblies **3** are disposed circumferentiality about the central shaft **6**.

In operation, the compressor assembly **2** inducts ambient air and compresses it. The compressed air travels through the flow path **10** to the compressed air plenum **8** defined by the casing **7**. Compressed air within the compressed air plenum **8** enters a combustor assembly **3** where the compressed air is mixed with a fuel and ignited to create a working gas. The heated working gas is typically at a temperature of between 2500 to 2900° F. (1371 to 1593° C.). The working gas passes from the combustor assembly **3** through the transition section **4** into the turbine assembly **5**. In the turbine assembly **5** the working gas is expanded through a series of rotatable blades **9**, which are attached to the shaft **6**, and a plurality of stationary ceramic vane assemblies **20**. As the working gas passes through the turbine assembly **5**, the blades **9** and shaft **6** rotate creating mechanical force. The turbine assembly **5** can be coupled to a generator to produce electricity.

The ceramic vane assemblies **20**, especially those adjacent to the transition sections **4**, are exposed to the high temperature working gas. To reduce thermal degradation of the vane assemblies **20**, the turbine assembly includes a casing **12** having cooling passages **14** therethrough. The casing cooling passages **14** are coupled to a cooling system **16**, such as an air or steam system. The casing cooling passages **14** are coupled to vane assembly main cooling passages **36** (described below).

As shown in FIG. **2**, the vane assemblies **20** have an inner endcap **22**, an outer endcap **24** and a body **26**. The end caps **22**, **24** are structured to be coupled to casing **12**. The body **26** is preferably an airfoil which, in operation, will have a high pressure side and a low pressure side. As shown in FIG. **3**, the body **26** includes a metallic core assembly **30**, a ceramic shell assembly **40**, and a support assembly **50**. As shown in FIG. **3**, the support assembly **50** is a compliant layer **52**, as will be described below. As shown in FIGS. **4** and **5**, respectively, the support assembly **50** may also be a plurality of hard contact points **54** or a biasing means **56**, both described below. As shown in FIG. **6**, the support assembly **50** may also be a combination of two or more of a compliant layer **52**, a plurality of hard contact points **54**, or a biasing means **56**.

As shown in FIG. **3**, the metallic core assembly **30** includes a frame **31**. The metallic core assembly **30** is coupled to, including being integral with, the inner endcap **22** and/or outer endcap **24**. As such, the metallic core assembly **30** bears almost all mechanical loading, including aerodynamic loading, during operation. The frame **31** of the metallic core assembly **30** form at least one main cooling passage **36** that extend between the outer endcap **24** and the inner endcap **22**. The main cooling passages **36** are in fluid communication with the cooling system **16**. As shown in FIG. **6**, the metallic core assembly **30** may also include at least one, and possibly two or more, spars **32**, and a metallic trailing edge assembly **34**. If a spar **32** is used, the metallic core assembly forms at least two cooling passages **36**.

As shown on FIG. **3**, the ceramic shell assembly **40** includes at least one layer, and preferably two layers, of a ceramic material **42**. The ceramic layer **42** is not bonded or fixed to the metallic core assembly **30**. The ceramic material **42**, as will be described below, is supported on the metallic core assembly **30** by the support assembly **50**. The ceramic layer may also extend over the end caps **22**, **24**. When there are more than one ceramic layers **42**, it is preferable to have an outer layer **44** and an inner layer **46**. The inner layer **46** is preferably a strain tolerant continuous fiber reinforced ceramic composite matrix which can deform to accommodate slight manufacturing tolerance mismatches and distortions due to loading such as AS-N720, A-N720, AS-N610, or A-N610 from COI Ceramics, 9617 Distribution Avenue, San Diego, Calif., 92121. The outer layer **44** may be a monolithic ceramic. The outer layer **44** is, however, preferably a high temperature insulating ceramic. The outer layer may have an outer coating such as a conventional environmental coating or thermal barrier **45**.

The ceramic shell assembly **40** is supported on the metallic core assembly **30** by the support assembly **50**. The support assembly **50** is coupled to, including being integral with, the metallic core assembly **30**. The support assembly **50** may include one or more of the following support members: a compliant layer **52**, a plurality of hard contact points **54**, or a biasing means **56**. As shown in FIG. **3**, the compliant layer **52** may be in the form of a continuous layer of material between the metallic core assembly **30** and the ceramic shell assembly **40**. Alternatively, as shown in FIG. **6**, compliant strips may be placed between hard contact points **54** (described below). Of course, any combination of a semi-continuous layer and strips may also be used. When a continuous compliant layer **52** is used, passages **53** (See FIG. **7**) may be formed therein to allow cooling fluid to reach the ceramic shell assembly **40** (described below). The compliant layer passages **53** are in fluid communication with the main cooling passages **36** of the metallic core assembly **30**. Alternatively, the compliant layer **52** may have a sufficiently porous consistency to allow a cooling fluid to pass therethrough to contact the ceramic shell assembly **40**.

The compliant layer **52** is preferably a feltmetal, such as Hastelloy-X material FM528A, FM515B, FM509D, Haynes 188 material FM21B, FM522A, or FeCrAlY material FM542, FM543, FM544, all from Technetics Corporation, 1600 Industrial Drive, DeLand, Fla. 32724-2095. When the compliant layer **52** is a feltmetal, the feltmetal may be bonded or brazed to the metallic core assembly **30**. The compliant layer **52** may also be a porous metallic foam, such as open cell foam made by Doucel ® Foams made by ERG, 900 Stanford, Calif., 94608 or closed cell foam made from hollow metal powders.

As used herein, a "hard contact point" may still be somewhat compliant. As shown on FIG. **4**, The hard contact points **54** are, preferably, raised ribs **55** which extend over the length of the body **26**. The hard contact points may be raised dimples as well. The ribs **55** may be formed integrally with the metallic core assembly **30** extending toward the ceramic shell assembly **40**, or the ribs **55***a* may be integral with the inner layer **46** and extend toward the metallic core assembly **30**. When the hard contact points **54** are formed as part of the ceramic shell assembly **40**, the ribs aid in heat transfer thereby increasing the effectiveness of the cooling system **16**. The hard contact points **54** are generally located on the high pressure side of the airfoil shaped body **26**. Between the ribs **55** are interstices **58**. The interstices **58** are in fluid communication with the main cooling passages **36**. As described above, strips of a compliant layer **52** may be disposed in the interstices **58**.

A vane assembly **20** having a biasing means **56** for a support structure **50** is shown in FIG. **5**. The biasing means **56** is preferably a plurality of leaf springs **57**, however, any type of spring may be used. The biasing means **56** maintains a supporting force on the ceramic shell assembly **40**. This supporting force also accommodates the differential thermal expansion between the metallic core assembly **30** and the ceramic shell assembly **40**. The biasing means **56** preferably interacts with the low pressure side of the body **26**. A cooling fluid may flow in and around the structure of the biasing means **56** and be in fluid communication with the ceramic shell assembly **40**.

The combination of the metallic core assembly **30**, ceramic shell assembly **40** and support assembly **50**, may be structured in many configurations. As shown in FIG. **4**, the ceramic shell assembly **40** may include a trailing edge portion **48** of the body **26**. As with the metallic trailing edge assembly **34**, the ceramic trailing edge portion **48** may include cooling passages **49** which are in fluid communication with the cooling system **16** via openings **60**. Another alternate design is shown in FIG. **7**. This embodiment includes a two piece metallic core assembly **30***a,* **30***b,* a ceramic shell assembly **40** having a two piece inner layer **46***a,* **46***b* and a one piece outer layer **44**, and a compliant layer **52** disposed between metallic core assembly **30***a,* **30***b* and the two piece inner layer **46***a,* **46***b*. FIG. **7** further shows a plurality of connecting passages **60** which are in fluid communication with the main passages **36** and the compliant layer **52**.

FIG. **8** shows another alternate embodiment. As before, this embodiment includes a two piece metallic core assembly **30***a,* **30***b,* and a ceramic shell assembly **40** having a two piece inner layer **46***a,* **46***b* and a one piece outer layer **44**. The support assembly **50** is a plurality of leaf springs **57**. Again the metallic core assembly **30** includes a plurality of connecting passages **60** that permit fluid communication between the main passages **36** and the support assembly **50**. A support pin **80** extending between the endcaps **22, 24,** may be used to reduce the movement between the inner layer portions **46***a,* **46***b*. Alternatively, as shown in FIG. **9**, the inner layer portions **46***a,* **46***b* may include deflections **82, 84** along an interface **86** to reduce the movement between the inner layer portions **46***a,* **46***b*.

As shown in FIG. **10**, the metallic core assembly **30** and ceramic shell assembly **40** may include a structural lock **90** formed by the metallic core assembly **30** and the inner layer **46***a,* **46***b*. The structural lock **90** includes tabs **91, 92, 93,** and **94,** which extend toward the interface **86** between the inner layer portions **46***a,* **46***b*. The inner layer portions **46***a,* **46***b* include tabs **95, 96, 97,** and **98** which are structured to extend around tabs **91, 92, 93,** and **94** respectively.

While specific embodiments of the invention have been described in detail, it will be appreciated by those skilled in the art that various modifications and alternatives to those details could be developed in light of the overall teachings of the disclosure. Accordingly, the particular arrangements disclosed are meant to be illustrative only and not limiting as to the scope of invention which is to be given the full breadth of the claims appended hereto and any and all equivalents thereof.

What is claimed is:

1. A vane assembly for a turbine assembly comprising:

an inner endcap;

an outer endcap;

a body:

said body comprises:

a metallic core assembly which is coupled to said inner endcap and said outer endcap;

a ceramic shell assembly;

a support assembly coupled to said metallic core assembly; and

said support assembly being disposed between said metallic core assembly and said ceramic shell assembly and adapted to transmit substantially all aerodynamic loads from said shell assembly to said core assembly during operation.

2. The vane assembly of claim **1**, wherein said support assembly is one or more of the structures selected from the group consisting of: a compliant layer, hard contact points and a biasing means.

3. The vane assembly of claim **2**, wherein said ceramic shell assembly comprises an inner layer of ceramic material and an outer layer of ceramic material.

4. The vane assembly of claim **3**, wherein said inner layer is a ceramic matrix composite.

5. The vane assembly of claim **4**, wherein:

said metallic core assembly comprises a frame forming at least one main cooling passage.

6. The vane assembly of claim **5**, wherein:

said frame includes a plurality of connecting passages that are in fluid communication with both said at least one main passage and said support assembly.

7. The vane assembly of claim **6**, wherein:

said support assembly hard contact points includes a plurality of ribs; and

said support assembly includes a plurality of strips of a compliant material disposed between said ribs.

8. The vane assembly of claim **3**, wherein said biasing means is a plurality of leaf springs.

9. The vane assembly of claim **8**, wherein:

said body has a high pressure side and a low pressure side; and

said plurality of leaf springs is disposed between said metallic core assembly and said ceramic shell assembly adjacent to said low pressure side and a plurality of ribs is disposed between said metallic core assembly and said ceramic shell assembly adjacent to said high pressure side.

10. The vane assembly of claim **3**, wherein said outer layer is an insulating ceramic.

11. The vane assembly of claim **10**, wherein said outer layer is ceramic insulation comprising hollow ceramic spheres.

12. A vane assembly for a turbine assembly comprising:

an inner endcap;

an outer endcap;

a body:

said body comprises:

a metallic core assembly which is coupled to said inner endcap and said outer endcap;

a ceramic shell assembly;

a support assembly coupled to said metallic core assembly; and

said support assembly being a layer of a compliant material, wherein said compliant material includes a plurality of cooling passages therethrough being in fluid communication with said ceramic shell assembly.

13. The vane assembly of claim **12**, wherein said ceramic shell assembly comprises an inner layer of ceramic material and an outer layer of ceramic material.

14. The vane assembly of claim **13**, wherein said inner layer is a ceramic matrix composite.

15. The vane assembly of claim **14**, wherein said outer layer is an insulating ceramic.

16. The vane assembly of claim **15**, wherein said outer layer is ceramic insulation comprising hollow ceramic spheres.

17. The vane assembly of claim **14**, wherein said metallic core assembly comprises a frame forming at least one main cooling passage.

18. The vane assembly of claim **17**, wherein said frame assembly includes a plurality of connecting passages that are in fluid communication with both said at least one main cooling passage and said support assembly.

19. The vane assembly of claim **1**, wherein said support assembly is a plurality of leaf springs.

20. The vane assembly of claim **19**, wherein said ceramic shell assembly comprises an inner layer of ceramic material and an outer layer of ceramic material.

21. The vane assembly of claim **20**, wherein said inner layer is a ceramic matrix composite.

22. The vane assembly of claim **21**, wherein said outer layer is an insulating ceramic.

23. The vane assembly of claim **22**, wherein said outer layer is ceramic insulation comprising hollow ceramic spheres.

24. The vane assembly of claim **23**, wherein:

said metallic core assembly comprises a frame forming at least one main cooling passage.

25. The vane assembly of claim **24**, wherein:

said frame assembly includes a plurality of connecting passages that are in fluid communication with both said at least one main cooling passage and said support assembly.

26. The vane assembly of claim **1** wherein said support assembly comprises a plurality of hard contact points and wherein said plurality hard contact points include a plurality of ribs extending from said ceramic shell assembly towards said metallic core assembly.

27. A turbine comprising:

a casing;

a cooling system; and

a plurality of vane assemblies comprising:

an inner endcap;

an outer endcap;

a body:

said body comprises:

a metallic core assembly which is coupled to said inner endcap and said outer endcap;

a ceramic shell assembly;

a support assembly coupled to said metallic core assembly; and

said support assembly being disposed between said metallic core assembly and said ceramic shell assembly and adapted to transmit substantially all aerodynamic loads from said shell assembly to said core assembly during operation.

28. The turbine of claim **27**, wherein said support assembly is one or more of the structures selected from the group consisting of: a compliant layer, hard contact points and a biasing means.

29. The turbine of claim **28**, wherein said ceramic shell assembly comprises an inner layer of ceramic material and an outer layer of ceramic material.

30. The turbine of claim **29**, wherein said inner layer is a ceramic matrix composite.

31. The turbine of claim **29**, wherein said outer layer is an insulating ceramic.

32. The turbine of claim **31**, wherein said outer layer is ceramic insulation comprising hollow ceramic spheres.

33. The turbine of claim **31**, wherein:

said metallic core assembly comprises a frame forming at least one main cooling passage.

34. The turbine of claim **33**, wherein:

said frame includes a plurality of connecting passages that are in fluid communication with both said at least one main passage and said support assembly.

35. The turbine of claim **34**, wherein:

said support assembly hard contact points includes a plurality of ribs; and

said support assembly includes a plurality of strips of a compliant material disposed between said ribs.

36. The turbine of claim **29**, wherein said biasing means is a plurality of leaf springs.

37. The turbine of claim **36**, wherein:

said body has a high pressure side and a low pressure side; and

said plurality of leaf springs is disposed between said metallic core assembly and said ceramic shell assembly adjacent to said low pressure side and a plurality of ribs is disposed between said metallic core assembly and said ceramic shell assembly adjacent to said high pressure side.

38. The turbine of claim **28**, wherein said support assembly is a layer of a compliant material.

39. A turbine comprising:

a casing;

a cooling system; and

a plurality of vane assemblies comprising:

an inner endcap;

an outer endcap;

a body:

said body comprises:

a metallic core assembly which is coupled to said inner endcap and said outer endcap;

a ceramic shell assembly;

a support assembly coupled to said metallic core assembly; and

said support assembly disposed between said metallic core assembly and said ceramic shell assembly, wherein said support assembly is a layer of a compliant material, wherein said compliant material includes a plurality of cooling passages therethrough being in fluid communication with said ceramic shell assembly.

40. The turbine of claim **39**, wherein said ceramic shell assembly comprises an inner layer of ceramic material and an outer layer of ceramic material.

41. The turbine of claim **40**, wherein said inner layer is a ceramic matrix composite.

42. The turbine of claim **41**, wherein said outer layer is an insulating ceramic.

43. The turbine of claim **42**, wherein said outer layer is ceramic insulation comprising hollow ceramic spheres.

44. The turbine of claim **41**, wherein said metallic core assembly comprises a frame forming at least one main cooling passage.

45. The turbine of claim **44**, wherein said frame assembly includes a plurality of connecting passages that are in fluid communication with both said at least one main cooling passage and said support assembly.

46. The turbine of claim **27**, wherein said support assembly is a plurality of leaf springs.

47. The turbine of claim **46**, wherein said ceramic shell assembly comprises an inner layer of ceramic material and an outer layer of ceramic material.

48. The turbine of claim **47**, wherein said inner layer is a ceramic matrix composite.

49. The turbine of claim **48**, wherein said outer layer is an insulating ceramic.

50. The turbine of claim **49**, wherein said outer layer is ceramic insulation comprising hollow ceramic spheres.

51. The turbine of claim **50**, wherein:

said metallic core assembly comprises a frame forming at least one main cooling passage.

52. The turbine of claim **51**, wherein:

said frame assembly includes a plurality of connecting passages that are in fluid communication with both said at least one main cooling passage and said support assembly.

53. A turbine assembly comprising:

a casing;

a cooling system; and

a plurality of vane assemblies comprising:

an inner endcap;

an outer endcap;

a body:

said body comprises:

a metallic core assembly which is coupled to said inner endcap and said outer endcap;

a ceramic shell assembly;

a support assembly coupled to said ceramic shell assembly;

said support assembly being disposed between said metallic core assembly and said ceramic shell assembly and adapted to transmit substantially all aerodynamic loads from said shell assembly to said core assembly during operation; and

said support assembly comprises a plurality of hard contact points.

54. The turbine assembly of claim **53** wherein said plurality hard contact points include a plurality of ribs extending from said ceramic shell assembly towards said metallic core assembly.

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